Remarks

These Remarks are in reply to the Office action mailed August 22, 2006.

I. Status of the Claims

Claims 2-16, 18-20, 27, 28, and 30-57 are pending in the application. Claim 17 is cancelled in this response. Claims 45-56 are withdrawn from consideration. Claim 6 was objected to. Claims 33 and 34 were rejected under 35 USC 112. Claims 57, 6, and 15-20 were rejected under 35 USC 102(e) as being anticipated by Chen, US Patent Publication No. 2003/0062594. Claims 2-5, 7-14, 27, 28, 30-32, and 35-44 were rejected under 35 USC 103(a) as being unpatentable over Chen.

II. Claim Objection: Claim 6

Claim 6 was objected to as failing to further limit the subject matter of a previous claim. Claim 6 depends from claim 2, which depends from claim 57.

Claim 57 recites a semiconductor device comprising: a silicide layer; a grown dielectric antifuse layer on and in contact with the silicide layer; and a conductive layer or semiconductor layer on and in contact with the grown dielectric antifuse layer, wherein the silicide layer and the grown dielectric antifuse layer are portions of the semiconductor device, and wherein the grown dielectric antifuse layer has suffered dielectric breakdown, such that an electrical connection exists between the silicide layer and the conductive layer or semiconductor layer.

Claim 2 adds the limitation that the silicide is selected from the group consisting of cobalt silicide, platinum silicide, nickel silicide, chromium silicide, palladium silicide, tantalum silicide, and niobium silicide.

Claim 6 adds the limitation that the conductive layer or semiconductor layer on and in contact with the grown dielectric antifuse layer is a conductive layer.

The Examiner protests that claim 6 does not further limit claim 57, saying:

> … the claim is objected to because it is redundant unto itself by saying that the conductive layer or semiconductor layer is a conductive layer. That is the nature of conductive and semiconductor layers.

Applicant will respectfully assert, however, that claim 6 in fact does further narrow the claimed subject matter. Claim 57 describes a layer as being a conductive layer or a semiconductor layer. A conductive layer is formed of a conductive material, such as a metal, or a conductive silicide; in short a layer which is always conductive. A semiconductor layer, in contrast, is formed of a semiconductor materal. The most commonly used semiconductor material, of course, is silicon, which is not always conductive; it is conductive if heavily doped with a conductivity-enhancing dopant, such as phosphorus or boron, or in certain temporary conditions, as in a field-effect transistor, when a voltage applied to a control gate causes a conductive channel to form in a layer of undoped or lightly doped semiconductor material. When the charge is removed from the control gate, the conductive channel disappears and the layer is no longer conductive. Other frequently used semiconductor materials are germanium or silicon-germanium alloys.

In claim 57, the layer in contact with the grown dielectric antifuse layer is *either* a conductive layer, or it is a semiconductor layer. In claim 6, however, a lighly doped or intrinsic semiconductor layer is explicitly excluded, and the layer in contact with the grown dielectric antifuse layer is a layer of conductive material. Thus Applicant respectfully suggests that claim 6 does in fact further limit the subject matter of claim 57, and requests that this claim objection be withdrawn.

III. <u>35 USC 112 Rejection: Claims 33 and 34</u>

Claims 33 and 34 were rejected under 35 USC 112 as being indefinite for failing to particularly point out and distinctly claim the subject matter which the Applicant regards as the invention.

Claim 33 recites the semiconductor device of claim 27 wherein, for any portion of the conductive layer more than about 20 angstroms thick, the density of the titanium nitride is less than about 4.0 grams per cubic cm.

Claim 34 recites the semiconductor device of claim 27 wherein, for any portion of the film more than about 20 angstroms thick, the resistivity of the titanium nitride is greater than about 300 microOhm-cms.

The Examiner protests:

> In re claims 33 and 34, the limitations "for any portion ..." are vague and indefinite because such phrase does not delineate to which portion applicant is referring.

Applicant will note that Applicant's intent is not to delineate a particular portion of the film; in fact the claim is intended to refer to *any* portion, so long as the thickness of the portion is more than about 20 angstroms thick. For example, suppose a titanium nitride film is 200 angstroms thick. Further suppose that the bottom 50 angstroms of the film has a density less than 4.0 grams per cubic cm, and that the remaining 150 angstroms of the titanium nitride film has a higher density, for example 4.33 grams per cubic cm. For a portion of this film, where the portion of the film is more than about 20 angstroms thick (in this example, 50 angstroms thick), the density of the titanium nitride is less than about 4.0 graphs per cubic cm; thus claim 33 would read on such a film. Claim 33 would also read on a film if the portion having lower density was at the top of the film, or in the middle, or if it were the entire film.

Applicant believes these claims to be clear as written, and believes that specifying a specific portion of the film, as the Examiner appears to be suggesting, would narrow the scope of the claims beyond Applicant's intent. However, Applicant wishes to make the claims as clear as possible, and invites the Examiner to suggest a clarification.

IV. <u>35 USC 102 Rejections over Chen</u>

Claims 57, 6, and 15-20 were rejected under 35 USC 102(e) over Chen. Claim 17 has been cancelled.

Claim 57 recites a semiconductor device comprising: a silicide layer; a grown dielectric antifuse layer on and in contact with the silicide layer; and a conductive layer or semiconductor layer on and in contact with the grown dielectric antifuse layer, wherein the silicide layer and the grown dielectric antifuse layer are portions of the semiconductor device, and wherein the grown dielectric antifuse layer has suffered dielectric breakdown, such that an electrical connection exists between the silicide layer and the conductive layer or semiconductor layer.

The Examiner finds a silicide layer in layer 56 of Fig. 8 and 9. Paragraph [0026] of Chen describes this layer as "a doped polysilicon layer, a doped amorphous silicon layer or a silicide layer."

The Examiner further considers the stack 60, show in Fig. 9, to be "a grown dielectric antifuse layer". Dielectric stack 60, in this figure, includes bottom oxide layer 57, silicon nitride layer 58, and top oxide layer 59. The Examiner considers the conductive layer or semiconductor

layer of claim 57 to be layer 66, for example of Figs. 10 and 11. Layer 66 is a metal conductive layer, as in paragraph [0028].

Applicant will concede that layer 56 may, in one embodiment, be silicide. Applicant will further concede that the dielectric rupture antifuse of Chen may include a grown dielectric layer. But Applicant will show that Chen does not teach the combination of a) a silicide layer, b) a grown dielectric antifuse layer on and in contact with the silicide layer, and c) a semiconductor or conductive layer on and in contact with the grown dielectric antifuse layer.

In paragraph [0027], Chen teaches formation of the preferred embodiment, including three layers, a bottom oxide layer 57, a silicon nitride layer 58, and a top oxide layer 59. The bottom oxide layer 57 is described this way:

> To form the ONO dielectric layer 60, a native oxide layer with a thickness of 10-50 angstroms is first formed on the surface of the silicon conductive layer 56 and functions as the bottom oxide layer 57.

This layer may be thermally grown, and is part of dielectric antifuse 60, a three-layer stack. But layer 57 is described by Chen as a native oxide, which is formed *on the surface* of silicon conductive layer 56. Thus layer 56 is not in contact with a silicide, as recited claim 57. The Examiner may suggest that paragraph [0026] teaches that layer 56 may be a silicide layer rather than a silicon layer, and thus that layer 57 may have been grown on silicide layer 56. Applicant believes this cannot be inferred, however. It is not conventional to grow an oxide layer on a silicide layer, and Chen gives no teaching of how to do so. Further, were an oxide grown on a silicide, it could not be described as a *native oxide*. The term "native oxide" is used to describe the oxide formed of a metal, semiconductor, or alloy such as silicon (silicon dioxide, SiO_2), aluminum (alumina, Al_2O_3), or an alloy of these materials. An oxide grown on a silicide is not conventionally described by the term "native oxide". Thus, in describing layer 57 as a native oxide, one skilled in the art would assume that this layer is grown on a silicon layer, not on a silicide layer. If a silicide layer were to be used as layer 56, the skilled artisan would assume that the bottom oxide layer in contact with this silicide layer was deposited rather than grown. There is no specific teaching in Chen of a grown dielectric antifuse layer on and in contact with a silicide layer.

The next layer in the antifuse stack 60 is silicon nitride layer 58. In paragraph [0027], Chen is clear that this layer is deposited, not grown; thus this layer cannot be considered a grown dielectric antifuse layer. The third layer 59 is an oxide or oxynitride layer which is formed by oxidizing

silicon nitride layer 58. This is arguably a grown dielectric antifuse layer, and it has a conductive layer 66 above and in contact with it. But the claim calls for the grown dielectric antifuse layer to be on and in contact with a *silicide* layer. Third layer 59 clearly is in contact with silicon nitride layer 58, not with a silicide, as in the claim.

Dielectric layer 60 itself cannot be described as a grown dielectric antifuse layer, since the largest thickness of it, silicon nitride layer 58, is deposited rather than grown.

The embodiment of Chen described in paragraphs [0026] through [0028], then, does not teach the specific combination recited in claim 57: a silicide layer, a grown dielectric antifuse layer on and in contact with the silicide layer, and a conductive or semiconductor layer on and in contact with the grown dielectric antifuse layer.

Toward the end of paragraph [0027], Chen states:

> However, the dielectric layer 60 is not limited to the ONO dielectric layer only, and other dielectric layer such as a single dielectric layer or a stacked dielectric layer composed of at least two dielectric materials are also applicable in the present invention.

Chen arguably teaches here that layer 60 may be a single layer, rather than the three-layer stack described in paragraphs [0026] and [0027], and pictured in Figs. 9 through 11. But Applicants can find no suggestion that this single layer should be a grown dielectric layer on and in contact with a silicide layer. As Applicant has explained, it is not conventional to grow a high-quality dielectric layer (as required for an antifuse) on a silicide layer. The only teaching of which Applicant is aware that suggests growing a dielectric layer on a silicide for use as a dielectric rupture antifuse appears in the teachings of the present invention, and use of this suggestion would be impermissible hindsight. Without specific teaching of a dielectric layer grown on a silicide layer, one skilled in the art would assume that a single-layer dielectric antifuse in Chen was either a) a silicon dioxide layer thermally grown on silicon, or b) a dielectric layer deposited on a silicide.

Applicant has shown that Chen does not teach or suggest the limitations of claim 57, and thus requests that the 35 USC 102(e) rejections of claim 57, and of its dependent claims 6, 15, 16 and 18-20, be withdrawn.

V. 35 USC 103 Rejections over Chen

Claims 2-5, 7-14, 27, 28, 30-32, and 35-44 were rejected under 35 USC 103(a) as being unpatentable over Chen. All of the claims included in this section depend from claim 57. In Section

IV of these remarks, Applicant explained that Chen does not teach the limitations of claim 57, and thus Applicants respectfully maintain that these claims also distinguish over the teachings of Chen.

Additionally, regarding the rejection of claim 9, the Examiner says:

> In re claim 9, Chen discloses the device of claim 2, but does not expressly disclose the conductor layer being a semiconductor layer. However, semiconductor layers are well known in the art to be used as conductor layers and it would have been obvious for one skilled in the art at the time of the invention to use a semiconductor layer as the top conductor, for the purpose, for example, of less process steps in switching from semiconductor to metal fabrication.

Applicants will point out, however, that claim 9 recites the semiconductor device of claim 2 wherein the conductor or semiconductor layer on and in contact with the grown dielectric antifuse layer is ***a lightly doped or intrinsic semiconductor layer***.

The Examiner will be aware that it is conventional in some devices to dope silicon (or other semiconductor materials) with conductivity-enhancing dopants such as boron (a P-type dopant) or phosphorus (an N-type dopant). The Examiner is correct that it is well-known to use a *heavily doped* semiconductor material as a conductor. Chen specifies in paragraph [0026] that silicon layer 56, which is intended to be conductive, is doped. When a semiconductor material is intended to be conductive, it will be heavily doped.

Claim 9, however, specifies that the layer on and in contact with the grown dielectric antifuse layer is *lightly doped or intrinsic* (undoped). Such a layer serves an entirely different electrical purpose. If a dielectric rupture antifuse separates a silicide layer from a heavily doped semiconductor layer, the contact made between these two layers when the antifuse is ruptured will be substantially *ohmic*, conducting current symmetrically in either direction. In contrast, if a dielectric rupture antifuse separates a silicide layer from a lightly doped or intrinsic semiconductor layer, the contact made between these layers when the antifuse is ruptured will be *rectifying*, forming a Schottky diode. Such a structure conducts current more readily in one direction than the other.

If one skilled in the art wished to replace the metal of Chen's conductor 66 with semiconductor material, it would be with *heavily doped* semiconductor material, which would cause the layer to have similarly conductive behavior. One skilled in the art would not replace a conductor with lightly doped or intrinsic semiconductor material, as the electrical behavior of the resulting device would be entirely different.

Claims 10, 11, and 12 all specify formation of, or the presence of, a Schottky diode, which will necessarily include a *lightly doped or intrinsic* semiconductor layer. As described, such a layer

is not taught or suggested by Chen, and one skilled in the art would not replace a conductive layer with a lightly doped or intrinsic semiconductor layer.

Claims 28 and 30 both include the limitations that the conductive layer is titanium nitride, and that the conductive layer forms a portion of a Schottky diode. The Examiner asserts that Chen teaches this Schottky diode, but does not identify any such teaching. Applicant can find no Schottky diode, and indeed can find no diode of any sort, taught or suggested by Chen. Applicant will remind the Examiner that a Schottky diode is formed at the junction of a metal (or metal-like material, such a silicide or titanium nitride) and an intrinsic or lightly doped semiconductor layer, preferably a lightly doped N-type layer (an n- layer). Applicant cannot identify such a junction in Chen. Claims 36-44 also include such a Schottky diode limitation, and thus also distinguish.

Applicant has shown that Chen does not teach or suggest the elements of claims 2-5, 7-14, 27, 28, 30-32, and 35-44 and respectfully requests reconsideration.

IV. Conclusion

Applicant believes this application to be in condition for allowance. Should further questions remain, the Examiner is invited to contact the undersigned agent by telephone.

The Commissioner is authorized to charge any underpayment or credit any overpayment to Deposit Account No. 501826 for any matter in connection with this response, including any fee for extension of time which may be required.

Respectfully submitted,

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